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(71) Applicant(s):
Siemens Aktiengesellschaft
(Incorporated in the Federal Republic of Germany)
Wittelsbacherplatz 2, 80333 München,
Federal Republic of Germany

(72) Inventor(s):
Stefan Stocker

(74) Agent and/or Address for Service:
Haseltine Lake & Co
Imperial House, 15-19 Kingsway,
LONDON, WC2B 6UD, United Kingdom

(54) Abstract Title: **Gradient coil system and method for producing a gradient coil system**

(57) A gradient coil system for a magnetic resonance device comprises the following features:
- a first coil is arranged on a first surface and a conductor arrangement is arranged on a second surface that is at a distance from the first;
- a conductor end of the first coil that is arranged in an inner region of the first surface is formed so as to be bent towards the second surface; and
- the conductor end is connected to the conductor arrangement in an electrically conductive manner.

A method for producing the gradient coil system is also disclosed.

FIG 6

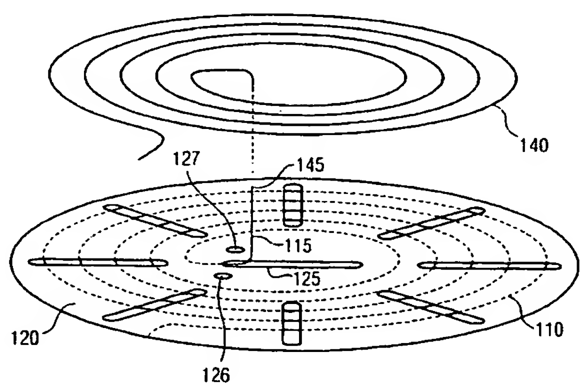

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FIG 1

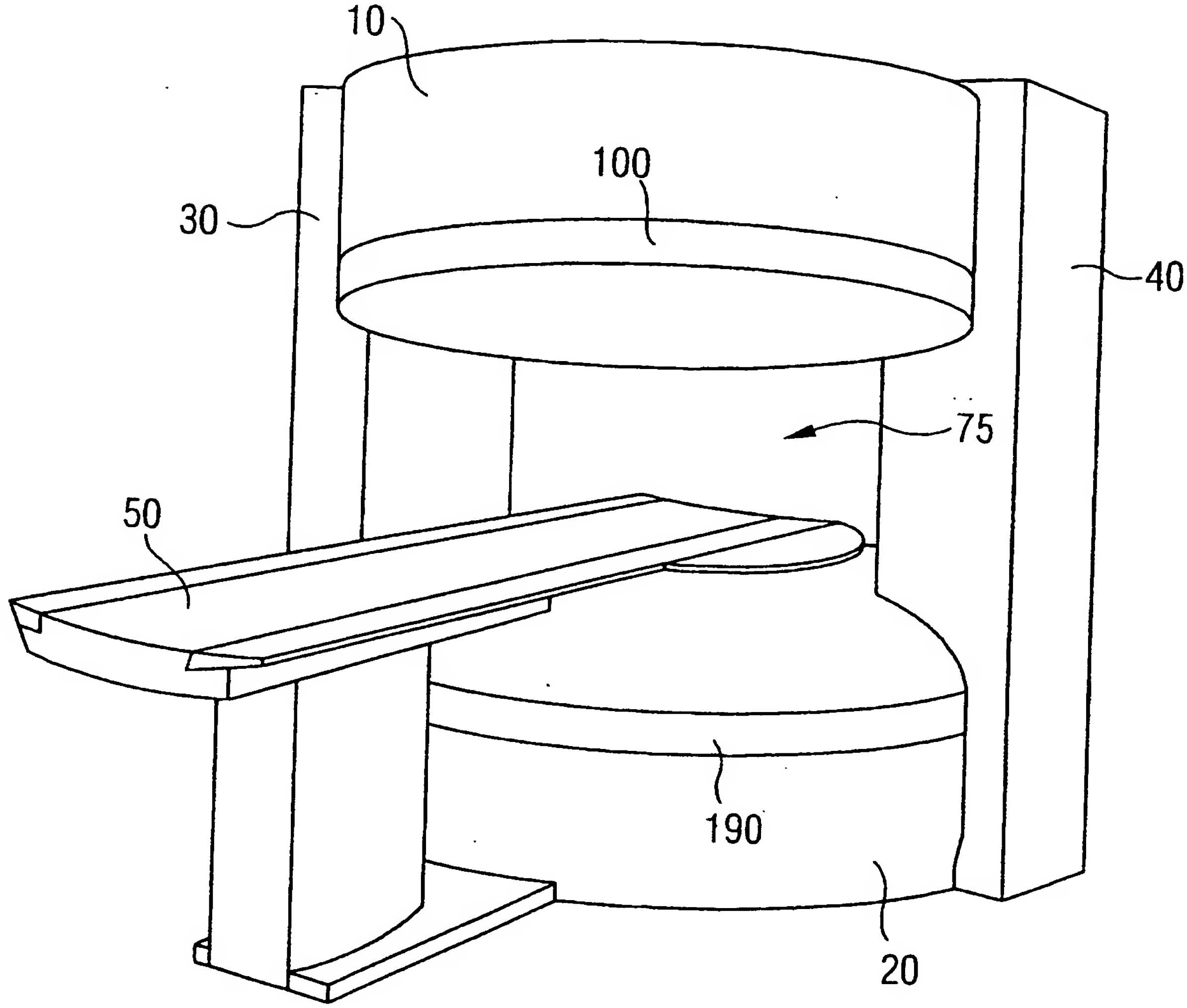


FIG 2

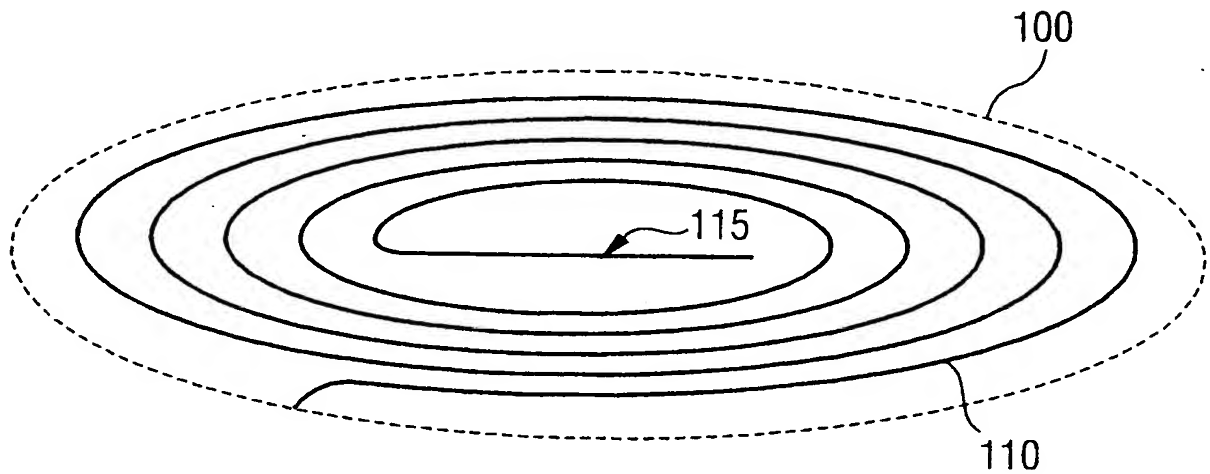


FIG 3

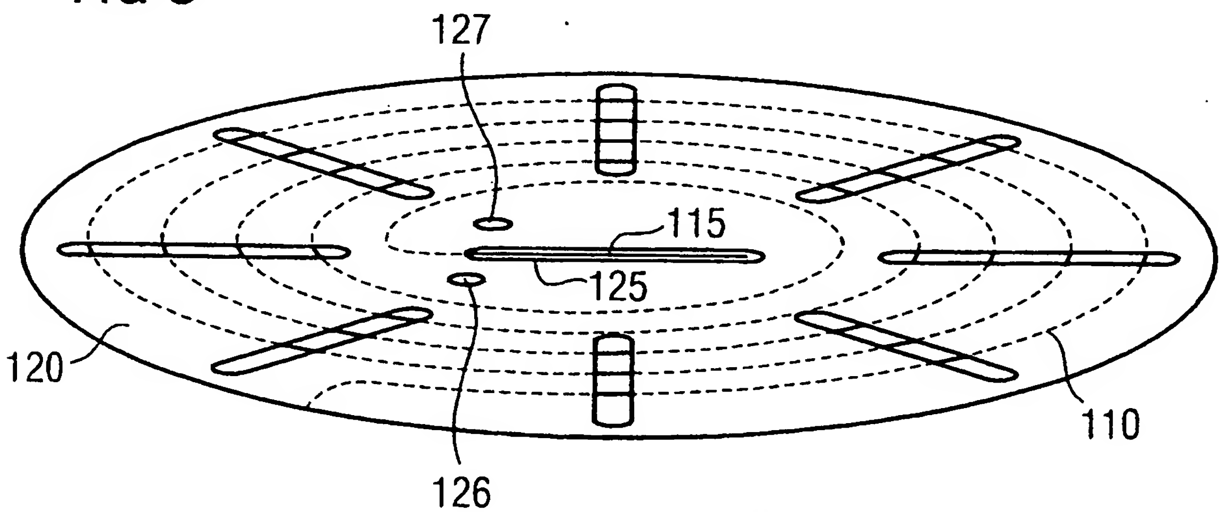


FIG 4

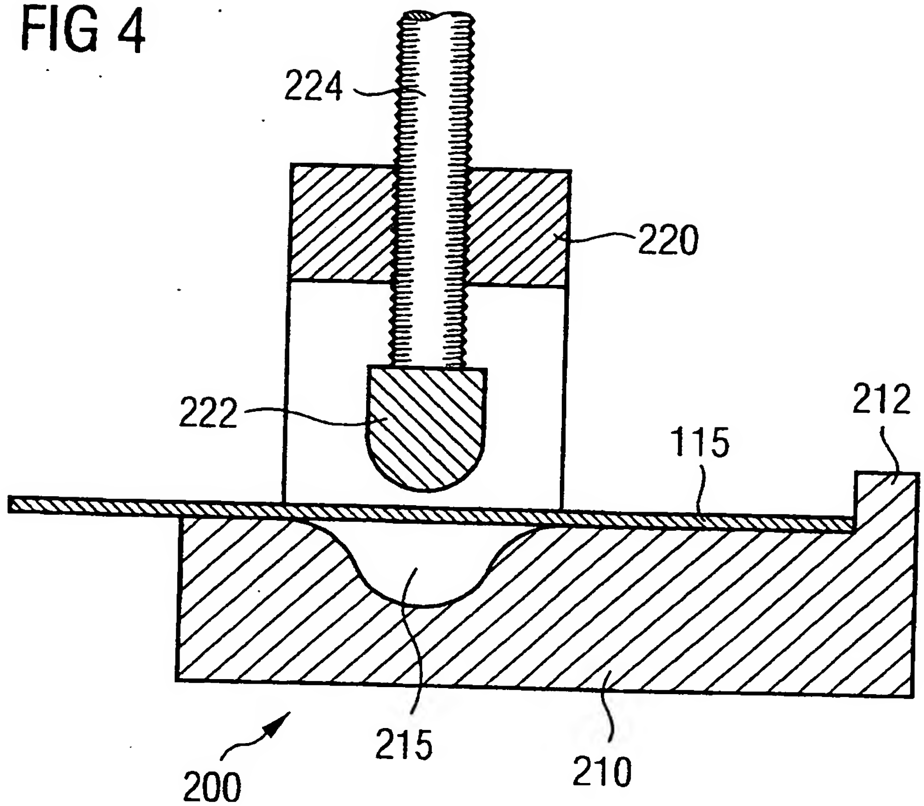


FIG 5

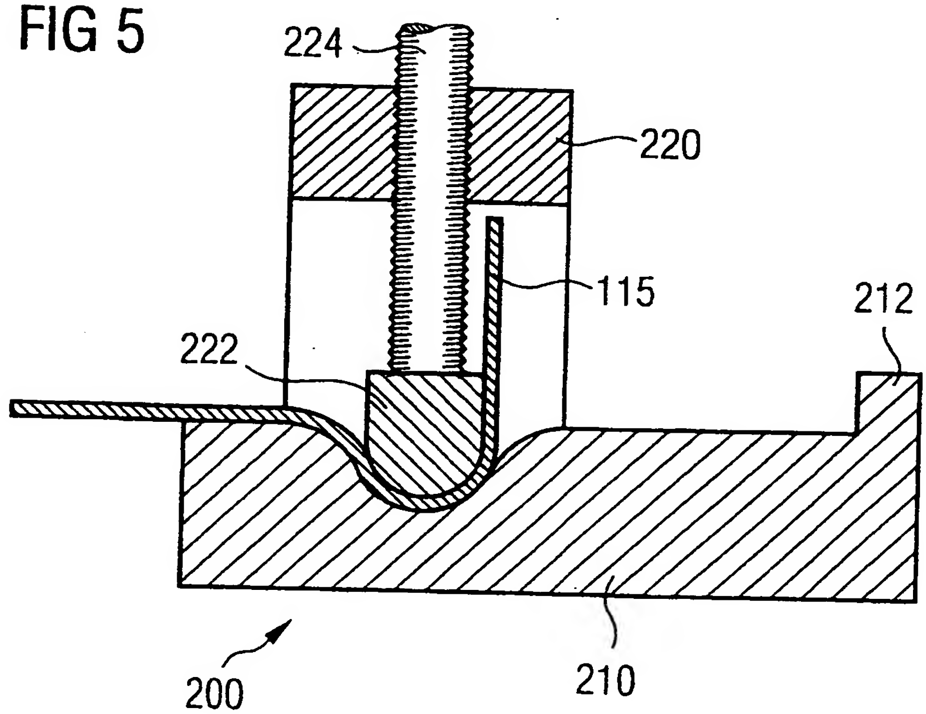
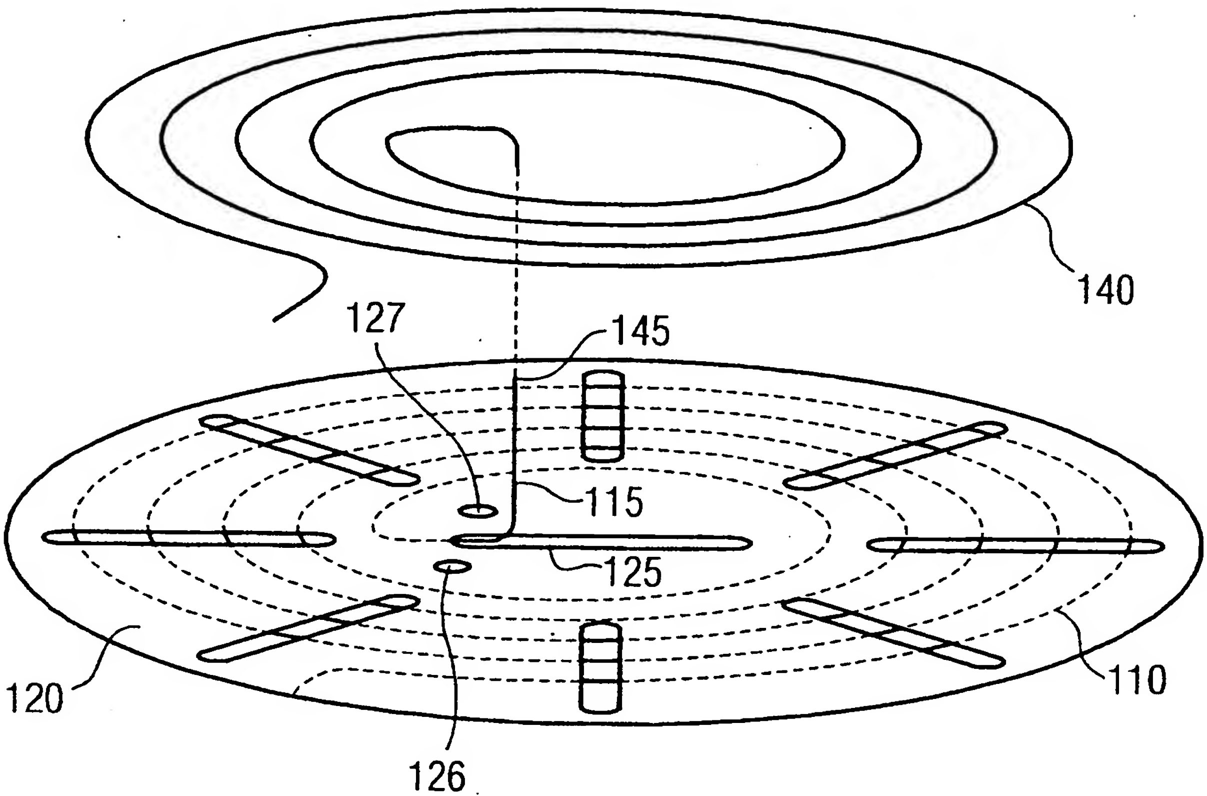


FIG 6



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GRADIENT COIL SYSTEM AND METHOD FOR PRODUCING A GRADIENT COIL SYSTEM

The invention relates to a gradient coil system and a method for producing a gradient coil system.

The magnetic resonance technique is a technique that is known for, among other things, obtaining images of the interior of a body of an object under examination. In this connection, in a magnetic resonance device, rapidly switched gradient fields, which are generated by a gradient coil system, are superimposed upon a static basic magnetic field, which is generated by a basic field magnet. Furthermore, the magnetic resonance device comprises a high-frequency system, which irradiates high-frequency signals into the object under examination in order to trigger magnetic resonance signals, and receives the triggered magnetic resonance signals, on the basis of which magnetic resonance images are created.

An actively screened gradient coil system for a magnetic resonance device that substantially consists of two discs and has an imaging volume that lies between the two discs is known, for example, from US 6,144,204. In this case, electrical connections are established for each disc between partial coils of the gradient coil system in that printed conductors of the partial coils project out in a finger-like or strip-like manner beyond the edge of the disc, are bent in a corresponding manner and are welded together.

Furthermore, it is known that in the case of an actively screened gradient coil system that

substantially consists of two discs, per disc the gradient coil and the associated screening coil, for the purpose of generating a gradient field with a gradient perpendicularly in relation to the circular surface of the discs, have a spiral conductor structure. In this case, connection points of the two coils that are substantially located in the centre of the disc can be connected together in an electrically conductive manner through other disc-like regions of the gradient coil system, for example for cooling devices, high-frequency screening devices and/or shim devices. For this purpose, when the gradient coil system is produced, in the first instance a solder connector is applied by means of soft-soldering at one of the connection points perpendicularly in relation to the circular surface. Subsequently, the other disc-like regions and the coil with the further connection point, which is connected to the solder connector likewise by means of soft-soldering, are installed and the whole is encapsulated with epoxide resin in order to form the disc.

An object of the present invention is to provide an improved gradient coil system in which an electrically conductive connection that is to be established within the gradient coil system is arranged in such a way that the establishment thereof can be effected with as little impairment as possible of mechanical and electrical properties of the gradient coil system.

According to the present invention there is provided a gradient coil system for a magnetic resonance device comprising the following features:

- a first coil is arranged on a first surface and a conductor arrangement is arranged on a second surface that is at a distance from the first;
- a conductor end of the first coil that is arranged in an inner region of the first surface is formed so as to be bent towards the second surface; and
- the conductor end is connected to the conductor arrangement in an electrically conductive manner.

The invention is based on the knowledge that in the case of the conventional procedure described above, in which one solder connector is used that is to be soft-soldered at two connection points, with the second soft-soldering the first or further soldered connections, which are often arranged at deeper points and so as to be inaccessible in the gradient coil system, come undone again. Hard-soldering that is associated with even greater heat development was, because of this, first ruled right out; it would have increased the risk of damage to insulating materials arranged in the immediate vicinity even further.

On the other hand, in the case of the gradient coil system in accordance with the present invention, on account of the bending of the conductor end, the connection point is displaced into a region that is less critical with regard to heat and only one connection needs to be established. The solder connectors that are realized as milled and expensive individual parts can be dispensed with, since the conductor end is guided on in a three-dimensional manner. As a result of the omission of at least one soldering step, the outlay on installation is also

reduced. Furthermore, fewer problems develop with solder splashes that occur when soldering and can give rise to short circuits.

Further advantages, features and details of the invention follow from the exemplary embodiment of the invention that is explained below, with reference to the figures. In the figures:

Figure 1 shows, in a perspective view, a magnetic resonance device with a planar gradient coil system which comprises two discs which are separate from each other;

Figure 2 shows, in a perspective view, a first partial coil that is arranged in one of the discs;

Figure 3 shows, in a perspective view, a carrier plate with the first partial coil sticking thereto;

Figure 4 shows a longitudinal section through a swage bending arrangement installed on the carrier plate in a starting position;

Figure 5 shows the swage bending arrangement after bending of a conductor end of the first partial coil has taken place; and

Figure 6 shows, in a perspective view, the first partial coil that is connected to a second partial coil.

Figure 1 shows, in a perspective view, a magnetic resonance device in which an upper and a lower cylindrical base element 10 and 20 are connected together by means of two columns 30 and 40. An imaging volume 75 extends between the base elements 10 and 20. Furthermore, the magnetic resonance device comprises a bearing arrangement 50 with which a region that is to be imaged of an object under examination that is mounted on the bearing arrangement 50 can be positioned in the imaging volume 75. In order to generate a static basic magnetic field that is as homogeneous as possible within the imaging volume 75, the magnetic resonance device comprises a basic field magnet, the portions of which are arranged at least in the base elements 10 and 20. In order to generate rapidly switchable magnetic gradient fields that are as linear as possible within the imaging volume 75, the magnetic resonance device comprises an actively screened, planar gradient coil system which substantially consists of an upper and a lower disc 100 and 190 encapsulated in casting resin. The discs 100 and 190 in this case have a diameter of approximately 1 m and a thickness of a few centimetres.

Figure 2 shows, in a perspective view, a first partial coil 110, which is arranged in the upper disc 100, in an intermediate step during the production of the upper disc 100, the edge of which is indicated by means of a broken line. In this case, the first partial coil 110 is part of a gradient coil of the gradient coil system for producing a gradient field with a gradient perpendicularly in relation to the circular surfaces of the discs 100 and 190. The first partial coil 110 is

in this case formed in a spiral manner on a planar surface. To this end, the conductor of the first partial coil 110 is inserted into grooves of an installation aid, which is not shown, with the grooves being milled in accordance with the desired conductor arrangement. Located substantially in the centre of the disc is one conductor end 115 which is to be connected to a second partial coil 140 in an electrically conductive manner through further disc-like regions of the upper disc 100, with the second partial coil 140 being assigned to a screening coil that is associated with the gradient coil.

An electrically insulating carrier plate 120, which is connected to the conductor by way of an adhering process under conditions of increased pressure and temperature, is laid upon the conductor of the first partial coil 110 that lies in the installation aid. After that, the carrier plate 120 can be removed from the installation aid with the conductor sticking thereto. The carrier plate 120 in this case has *inter alia* in the centre of the carrier plate a cut-out 125 which enables there to be unhindered access to the conductor end 115 at least from below and above. Figure 3 shows, in a perspective view, the carrier plate 120 with the first partial coil 110 adhered to the underside of the carrier plate 120, with the sections of the conductor of the first partial coil 110 that are covered by the carrier plate 120 being shown in broken lines.

In order to establish the electrical connection between the two partial coils 110 and 140, the conductor end

115 is to be bent in such a way that the conductor end 115 is aligned so as to be perpendicular to the carrier-plate surface, pointing upwards towards the second partial coil 140. To this end, a swage bending arrangement 200, which is shown in greater detail in Figures 4 and 5, is temporarily installed close to the central point of the carrier plate 120. In this case, a swage base element 210 of the swage bending arrangement 200 is arranged underneath the carrier plate 120 and underneath the conductor end 115 and is screwed by means of cylinder-shank screws by way of two bores 126 and 127, introduced in the carrier plate 120, to a guide element 220 of the swage bending arrangement 200 that is to be arranged on top, on the carrier plate 120 and above the conductor end 115. The bores 126 and 127 in the carrier plate 120 with accuracy of fit thereby cause the swage bending arrangement 200 to be forced to be positioned correctly for the bending of the conductor end 115, as desired.

Figure 4 shows a longitudinal section through the installed swage bending arrangement 200 in a starting position with the conductor end 115 still bent down. In this connection, the conductor end 115 is laid on the swage base element 210 that has a recess 215, with a stop 212 of the swage base element 210, in addition to the bores 126 and 127 in the carrier plate 120, guaranteeing correct positioning of the swage bending arrangement 200 for the bending, as desired. The swage bending arrangement 200 further comprises a plunger 222 which can be pressed into the recess 215 by way of a threaded rod 224, rotatably mounted in the guide element 220, in order to bend the conductor end 115.

By means of appropriate rotation of the threaded rod 224, the plunger 222 is lowered into the recess 215 so that the conductor end 115 is bent perpendicularly in relation to the carrier plate surface. Figure 5 shows therefor the swage bending arrangement 200 after the bending process has taken place.

After the conductor end 115 has been bent as described above, the swage bending arrangement 200 is removed and further disc-like regions of the upper disc 100, containing cooling and/or shim devices, and also the second partial coil 140, are set up on the carrier plate 120. In this connection, the bent-up conductor end 115 of the first partial coil 110 is connected in an electrically conductive manner to a conductor end 145 of the second partial coil 140 by soldering. The afore-mentioned set-up is shown in a corresponding manner in a perspective view in Figure 6, with, for reasons of clarity, the two partial coils 110 and 140 being shown at a comparatively great distance from each other in the manner of an exploded view and with regions arranged between the partial coils 110 and 140, comprising the afore-mentioned cooling and/or shim devices, not being shown. After further addition of further partial coils for further gradient coils and associated screening coils, the whole structure is encapsulated in casting resin in order to form the upper disc 100. A corresponding procedure is carried out when the lower disc 190 of the planar gradient coil system is produced.

What has been described above can also advantageously be applied in a corresponding manner to partial coils of hollowly cylindrical gradient coil systems.

List of reference numerals

10, 20	Base element
30, 40	Column
50	Bearing arrangement
75	Imaging volume
100	Upper disc of a planar gradient coil system
110	First partial coil
115	Conductor end of the first partial coil
120	Carrier plate
125	Cut-out in the carrier plate
126, 127	Bore in the carrier plate
140	Second partial coil
145	Conductor end of the second partial coil
190	Lower disc of the planar gradient coil system
200	Swage bending arrangement
210	Swage base element
212	Stop on the swage base element
215	Recess in the swage base element
220	Guide element
222	Plunger
224	Threaded rod

Claims

1. Gradient coil system for a magnetic resonance device comprising:

- a first coil arranged on a first surface and a conductor arrangement arranged on a second surface that is at a distance from the first;
- wherein a conductor end of the first coil that is arranged in an inner region of the first surface is formed so as to be bent towards the second surface; and
- the conductor end is connected to the conductor arrangement in an electrically conductive manner.

2. Gradient coil system according to claim 1, wherein the conductor arrangement also has a conductor end which for the purposes of connection with the conductor end of the first coil is formed so as to be bent in accordance with the conductor end of the first coil.

3. Gradient coil system according to one of claims 1 or 2, wherein the conductor arrangement is formed as a second coil.

4. Gradient coil system according to one of claims 1 to 3, wherein the coils are formed as partial coils of a gradient coil and/or screening coil.

5. Gradient coil system according to one of claims 1 to 4, wherein at least one of the surfaces is planar.

6. Gradient coil system according to one of claims 1 to 5, wherein the electrical conductive connection is established by soldering or welding.

7. Gradient coil system according to one of claims 1 to 6, wherein at least one of the coils has a spiral conductor arrangement.

8. Method for producing a gradient coil system according to one of claims 1 to 7, comprising the following steps:

- a conductor of the first coil is arranged on the first surface in a predetermined shape; and
- the conductor end in the inner region of the first surface is bent towards the second surface.

9. Method according to claim 8, wherein the conductor of the first coil is inserted into grooves of an installation aid in order to form the predetermined shape.

10. Method according to one of claims 8 or 9, wherein a carrier is connected to the first coil by way of an adhering process.

11. Method according to one of claims 8 to 10, wherein the bending is effected by means of a swage bending arrangement.

12. Method according to claim 11, wherein the swage bending arrangement is formed from at least one swage base element and a guide element guiding a plunger,

which elements are connected together on both sides of the conductor end.

13. Method according to claim 12, wherein the carrier has bores which position the swage bending arrangement and via which the swage base element and the guide element are screwed together.

Application No: GB 0317748.2
Claims searched: 1-13
Examiner: John Cockitt
Date of search: 9 March 2004

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X,E	1 at least	WO03/025610A1 KONINK PHILIPS - see fig 1
A		US4794338A GEN ELECTRIC

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^W:

G1N

Worldwide search of patent documents classified in the following areas of the IPC^7:

G01R

The following online and other databases have been used in the preparation of this search report:

ONLINE: EPODOC, WPI, JAPIO